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A NOTE ON SOME USES OF $\theta$-S SECTIONS

by

J. G. Bruce

September 1981

TECHNICAL REPORT

*Prepared for the Office of Naval Research under Contract N00014-79-C-0071; NR 083-004.*

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Approved for Distribution: Valentine Worthington, Chairman
Department of Physical Oceanography

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# A Note on Some Uses of $\theta$-S Sections

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Isohalines plotted against temperature and horizontal distance along a hydrographic section can be used to observe changes in the T-S or $\theta$-S relationship of water masses. By using this technique, eddies formed off the Somali coast during the southwest monsoon, or Gulf Stream eddies having their own individual T-S characteristics, may be identified.

It is sometimes useful to display the changes occurring either spatially or temporally in the temperature-salinity relationship of a type of water. Such can be achieved by constructing a T-S or $\theta$-S section in which the isohalines are plotted with temperature and horizontal distance being the coordinates. In regions where no change of $\theta$-S occurs along a section of stations, the isohalines have a zero slope, whereas for large changes the slope would have a high value.

A $\theta$-S section is useful in depicting the near-surface structure such as found in the Somali eddies [*Bruce*, 1968] in the Indian Ocean formed during the southwest monsoon. Here the relatively fresh (<35.2‰) coastal water advected northward by the Somali Current becomes entrained in the eddy structure. Figure 1 shows the near symmetry of the characteristics of the prime eddy [*Bruce*, 1979] (west of approximately 56°E) about the eddy center (~54°E). The eddy is anticyclonic, and apparently some mixing along the northern boundary occurred with the warmer more saline water to the north after the eddy turned offshore at 51°30′E, because the eastern boundary (56°E) shows an increase in salinity for the same values of temperature. To the east another anticyclonic eddy also is shown centered about 58°E, again with a slight asymmetry of T-S characteristics caused by mixing of near surface water along its northern edge.

Whereas the southwest monsoon attains full strength during July and August, the weaker northeast monsoon reaches a

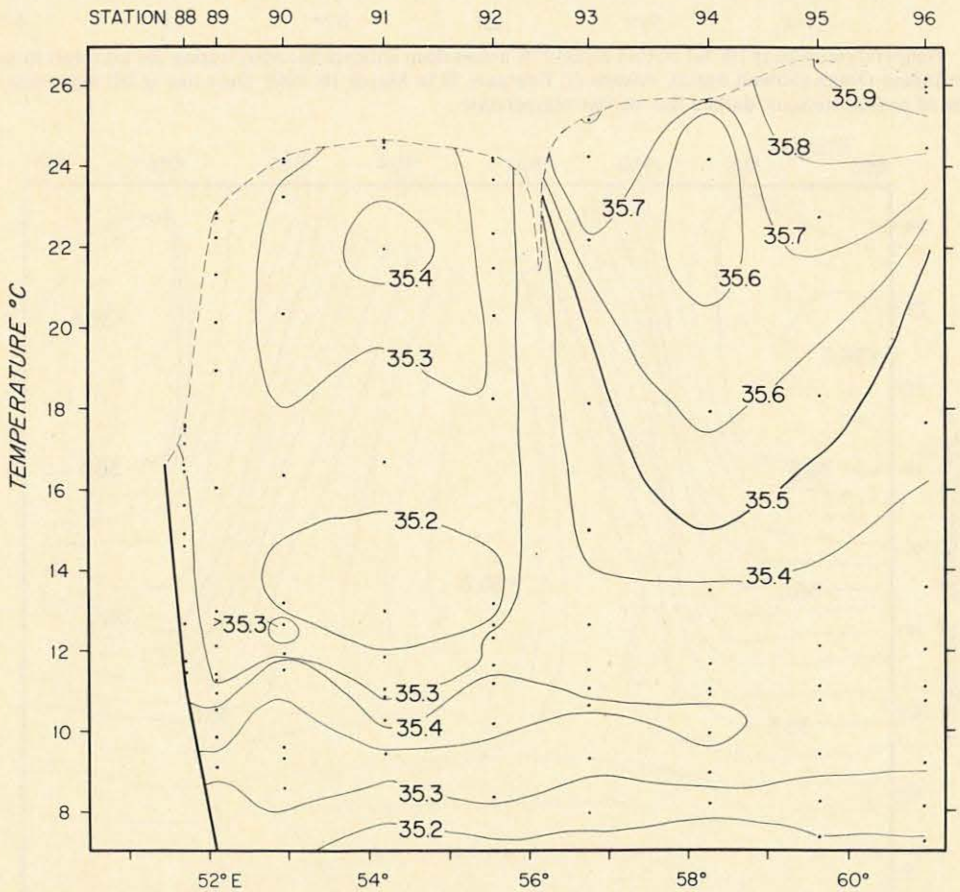


Fig. 1. Temperature-salinity (in ‰) section along 10°N across anticyclonic eddies during the southwest monsoon in the western Indian Ocean (Somali Basin), *Atlantis II*, August 29 to September 1, 1963. Dark line lower left represents bottom temperature of coastal stations; dashed line surface temperature.



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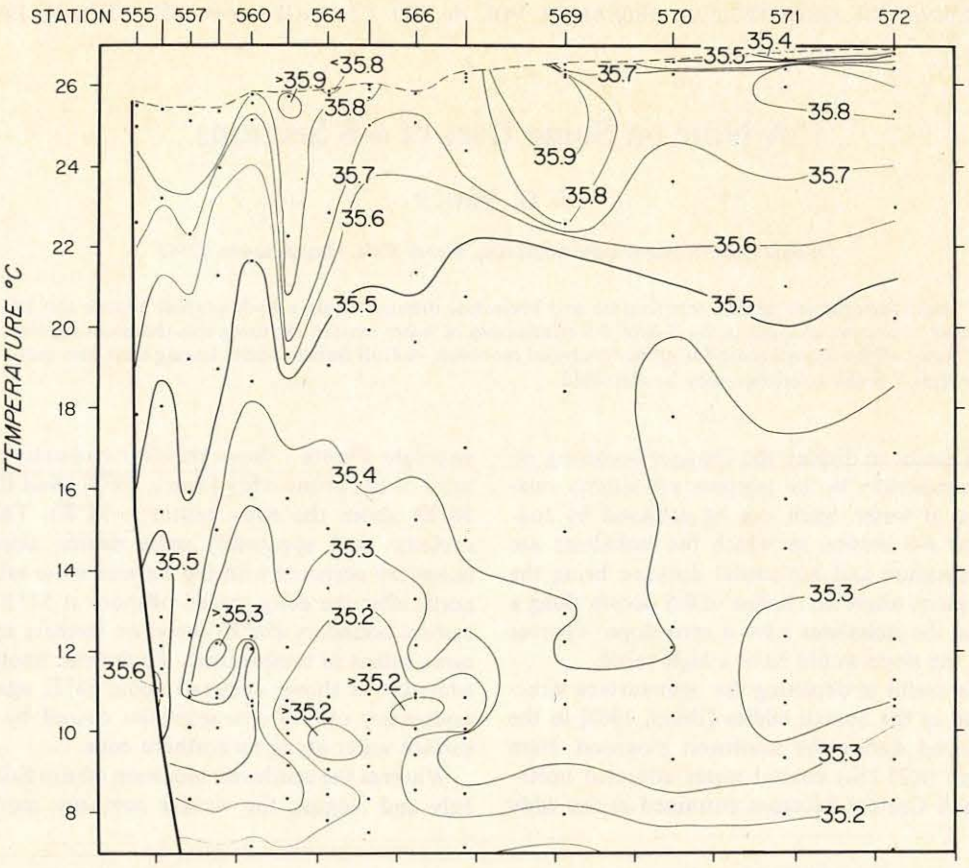


Fig. 2. Temperature-salinity (in ‰) section along 9°N across deep anticyclonic eddy during the northeast monsoon in the western Indian Ocean (Somali Basin), *Atlantis II*, February 28 to March 10, 1965. Dark line at left represents bottom temperature of coastal stations; dashed line surface temperature.

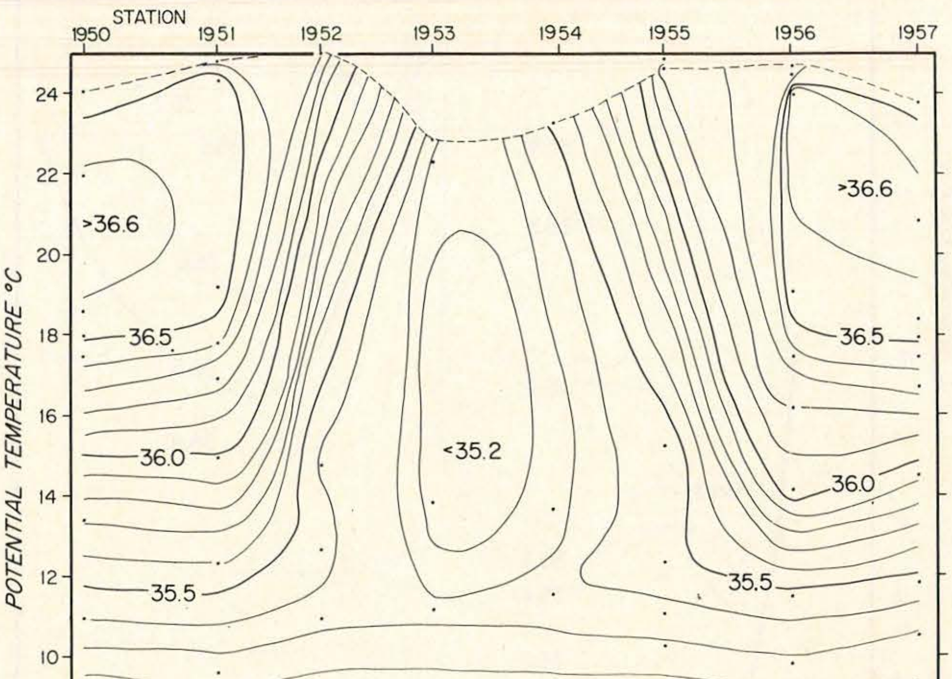


Fig. 3. Potential temperature-salinity (in ‰) section from north (at 37°30′N) to south (at 35°45′N) along 66°40′W across Gulf Stream cyclonic ring (detached), *Crawford*, October 10–12, 1965. Dashed line represents surface temperature.

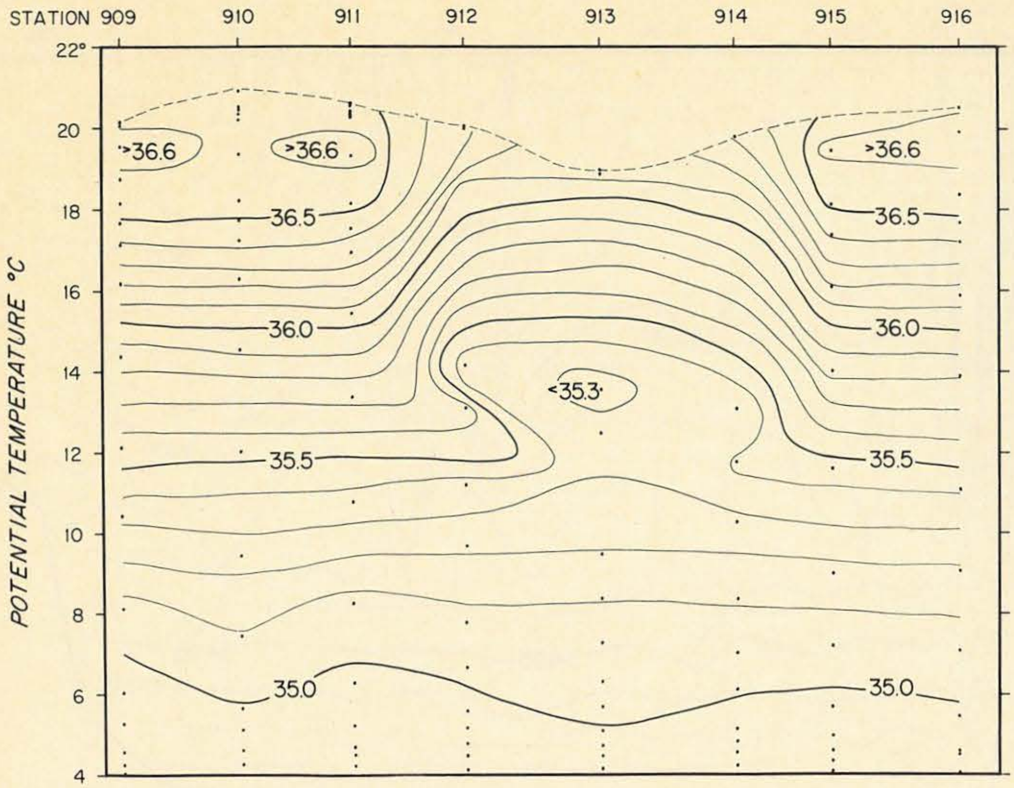


Fig. 4. Potential temperature-salinity (in ‰) section from north (at 37°29'N) to south (at 35°44'N) along 66°05'W across same Gulf Stream cyclonic ring 3 months later as shown in Figure 3, *Atlantis II*, January 11–12, 1966. Dashed line represents surface temperature.

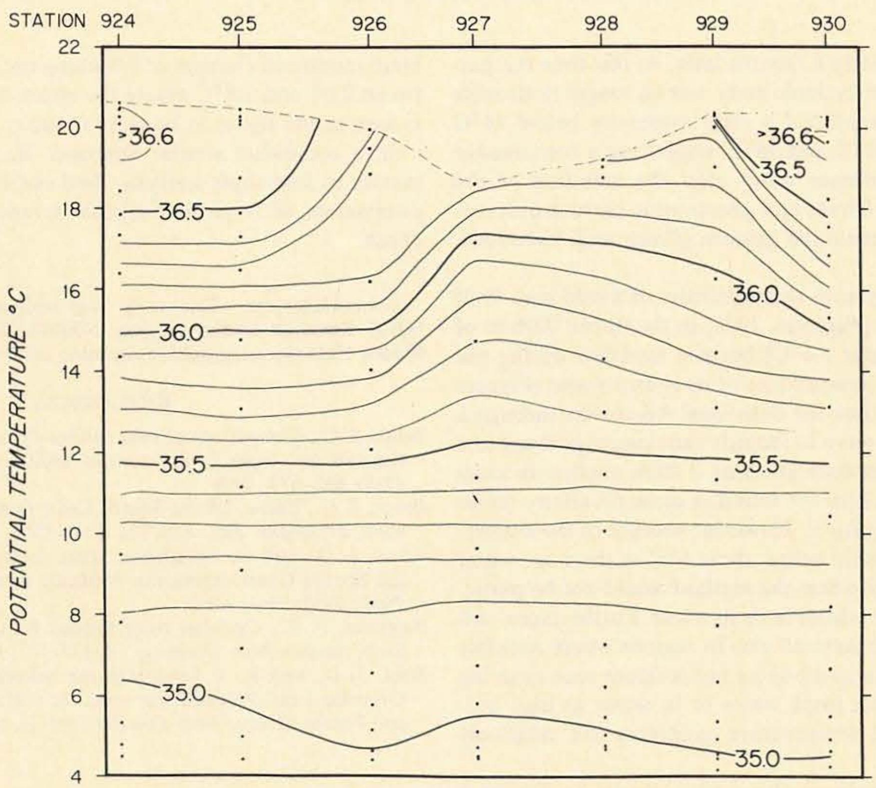


Fig. 5. Potential temperature-salinity (in ‰) section from north (at 37°04'N) to south (at 35°36'N) along 63°30'W across another Gulf Stream cyclonic ring separate from that in Figure 4 showing how isohalines would approach zero slope with increasing age of ring isolated in Sargasso Sea. *Atlantis II*, January 18–19, 1966. Dashed line represents surface temperature.

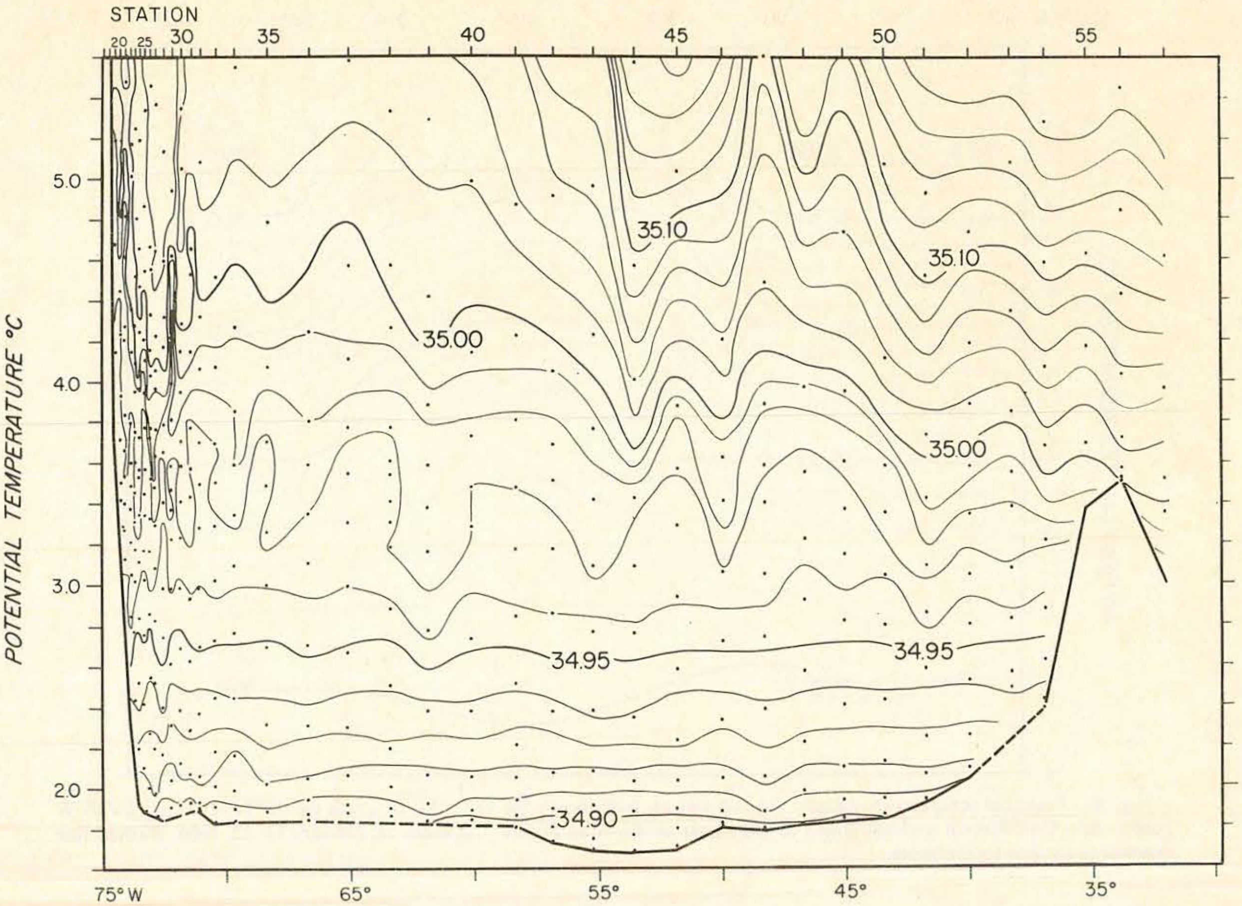


Fig. 6. Potential temperature-salinity (in ‰) section from west to east along 36°15′N for temperatures <5.6°C. *Chain*, April 19 to May 3, 1959.

maximum approximately 6 months later. At this time the pattern of the Somali anticyclonic eddy was no longer noticeable above 14°C, but it exhibited a clear symmetry below 14°C (Figure 2) between 52°E and 56°E, suggesting a continuance of the eddy in the deeper water after the cessation of the southwest monsoon. Direct and geostrophic current observations support this circulation pattern [*Bruce and Volkmann*, 1969].

The temperature-salinity characteristics of a cold core Gulf Stream cyclonic ring [*Fuglister*, 1972] in the upper 1000 m of the Sargasso Sea (water >6°C) become modified during the age of the eddy now independent of its source water (Figures 3 and 4). At any one time the individual $\theta$-S section through a single eddy can then serve to identify (analogous perhaps to a fingerprint) and aid in distinguishing it from another in cases where two or more eddies are found in close proximity (compare Figure 4 with Figure 5). However, because of the similarity of the $\theta$-S relationship below about 6°C of the slope water and that of the Sargasso Sea, the method would not be particularly useful for these eddies in deep water. Furthermore, difficulties would be encountered also in regions where multiple values of salinity occur at the same temperature such as in the upper North American slope water or in water at high latitudes where vertical temperature gradients are relatively weak.

On a large scale such as the section shown in Figure 6 across the North Atlantic, the method can be used to examine regions where relatively small changes occur in deep water. Here minimum changes of $\theta$-S along the section are found between 2.0° and 2.8°C where the mean slope of the isohalines is seen in the figure to be close to zero.

In a somewhat similar approach in studying deep water masses by isentropic analysis, *Reid and Lynn* [1971] have used parameters of $\sigma$ plotted against temperature, salinity, and depth.

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1. Water mass identification
2. Temperature-salinity characteristics
3. Eddy structure off Somalia and in Sargasso Sea

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Isohalines plotted against temperature and horizontal distance along a hydrographic section can be used to observe changes in the T-S or $\theta$-S relationship of water masses. By using this technique, eddies formed off the Somali coast during the southwest monsoon, or Gulf Stream eddies having their own individual T-S characteristics, may be identified.

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